ON AN IMPORTANT SPECIMEN OF EDESTUS; WITH DESCRIPTION OF A NEW SPECIES, EDESTUS MIRUS.

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The fine specimen of *Edestus* here described, and now the property of the United States National Museum (Cat. No. 7255), was discovered about 18 years ago by a miner of coal at Lehigh, Webster County, Iowa. Through the intelligent interest of Mr. R. A. Peterson, of Lehigh, the specimen was recently sent to the United States National Museum for examination, and for this purpose it was placed in the hands of the writer. From correspondence with Mr. Peterson it has been learned that the remains were discovered in the black shale which overlies the bed of coal that is locally known as the Tyson seam, and at a depth of 165 feet from the surface. From the coal the specimen was separated by a thin layer of sandstone. Further remarks on the geological position of this coal will be made below.

The specimen so fortunately discovered represents apparently a species hitherto unknown; but what is of still greater importance is the fact that it appears to explain the relation of the objects known by the name of *Edestus* to the body of the animal that bore them, and we can hardly doubt that the same explanation will apply to the still more remarkable objects known as *Toxoprion*, *Helicoprion*, and *Lissoprion*. Among those who have occupied themselves in the study of the straight, or bent, or coiled structures which bear the names mentioned, there has been much dispute regarding the position which they had in the body, especially as to whether they belonged in the mouth or in the neighborhood of some of the fins. In a paper published not long ago [1] the writer advocated the proposition that the toothed shafts of *Edestus* and even the toothed whorls of *Helicoprion* had been produced in front of some of the median fins of sharklike animals. In the presence of the specimen here described this fine theory vanishes, for the remains seem to indicate distinctly that the tooth-bearing shafts of *Edestus* belonged to the region of the mouth and nowhere else.

[1] Proc. U. S. Nat. Mus., 1909, vol. 37, pp. 43-61.

The remains consist, as interpreted, of two tooth shafts, one belonging to the upper jaw, the other to the lower; a part of the lower jaw, and the anterior end of the cranium. There seem to be few or no remains that represent the upper jaws or palato-quadrate arch. As is too often the case, the absence of parts that might have been secured is to be regretted. On the left of the block of shale, as represented in plate 1, the cranium extends to the edge, and there is no doubt that it continued into the block adjacent. Probably near by, in other directions, there were scattered portions of the skull. Of less importance is the fact that the apices of some of the teeth were lost after the block was split.

The parts, except the teeth and the shafts bearing them, are composed of calcified cartilage. The natural surface of most of this appears to be somewhat regularly pitted, and this pitting is believed to be due to the presence of shagreen scales, each of which seems to have had a central depression. The shaft that belonged to the upper jaw has a greater diameter than that pertaining to the lower jaw. It is also longer and not so strongly curved. The upper shaft has a length of about 185 mm., but a portion is missing from the front and possibly a fragment is gone from the hinder end. The diameter about the middle of the length is 32 mm. The lower shaft has a length of about 150 mm. The diameter is 26 mm. In the upper shaft six teeth are distinguishable, but one is missing from the front end, while two others are seen in section on the left-hand edge of the block (pl. 1, *16*, *17*), but do not show in the figure.

The teeth have a height of about 28 mm., in a straight line from the apex to the middle of the base. One margin, the anterior, is convex, the other concave. Each margin possesses about 25 denticulations, those of the anterior border being slightly larger. Most of the denticulations are simple, but a few of them have one or more notches near the summit. The hinder part of the lower shaft (pl. 1, *3*), including two teeth, had, at the time of burial, suffered dislocation. One of these teeth is seen at *4* (pl. 1 and pl. 2, fig. 2); the other lies under the fifth tooth of the upper shaft and was found by digging through the block from the other side (pl. 2, fig. 2, *18*). It is evident that the hinder segments of the shaft had not yet become thoroughly consolidated and that maceration and a slight disturbance had led some displacement. On the upper border of the shaft, behind the fifth tooth, is a groove into which the base of the displaced sixth tooth had fitted. Counting the two displaced teeth, there would be seven in the lower shaft. However, in the excavation made from the underside of the block, there is seen a tooth (pl. 2, fig. 2, *19*) that is free from any part of a shaft. It appears possible that this tooth belonged behind the one indicated by the numeral *4* and had not yet

developed its portion of the shaft. The hinder end of the detached portion of the shaft is irregular, as if some part had been eroded away.

Figure 1 of plate 2 represents the right half of the block that inclosed the specimen, while figure 2 presents a view of the teeth that were exposed by digging through from the underside of the block. In figure 1 are seen impressions of the teeth of the lower shaft and three of those (*5*, *6*, *7*) of the upper shaft. In the depression which contained the lower shaft is seen a fragment, *2*, of the latter, which split off from the main portion. Behind and below this depression is seen a large mass of calcified cartilage, which evidently belonged to the lower jaw, including the symphysis. The upper and anterior part of this, *8*, forms a part of the bottom of the depression mentioned and must have passed, partly at least, on the right-hand side of the shaft, which would be the upper side on plate 1. Below and behind this there is another mass, *9*, which was probably in contact with the left side of the shaft, but in the fossil does not quite reach it (pl. 1) on account of some distortion or shoving before burial. At *10*, plate 2, is seen another part of the lower jaw. This ascended to the point indicated by *7*, as is shown by the impression on the matrix. It overlay, that is, passed to the right of, the fragment of the lower shaft and over the teeth *11* and *12*, which point forward from the hinder edge of the block. What appears to be a continuation of this cartilage is seen at *13*, plate 1, passing under (to the left of) the tooth *6*. This cartilage does not appear to be a part of that which supports the two teeth *11* and *12*, for there is a thin layer of matrix between them. Nevertheless, it seems probable that these teeth belonged to one of the jaws, upper or lower. Still another tooth resembling these and having its apex pointed in the same direction is seen at *20*, plate 2, figure 2. None of these three is attached to a shaft, and they are straighter than are the teeth of the shafts. The exposed surface of the bases of these teeth is rough and appears to indicate that some part had been broken or eroded off.

Returning to the lower jaw, it is to be observed that the symphysis appears to have been at least 85 mm. long, occupying the full length of the cartilage present. Since the lower shaft was developed along this symphysis, the latter, as a bed for the former, might be expected to be considerably elongated.

Above the upper shaft is seen a mass of calcified cartilage, which is regarded as having belonged to the snout and extending about as far backward as the orbit. It is even possible that a part of the orbit is included. Below the numeral *14*, plate 1, is a deep pit, which is thought to be the nasal pit of the right side. It is surrounded by a pavement of shagreen scales, each of which presents a central depression. There seems to be a channel running forward from it to the

border of the cartilage of the snout. Above this pit there was an overhanging ridge that ran forward from the pit about 15 mm. and backward from it about 35 mm. In cleaning the specimen this ridge split off and it was not replaced before photographing, in order that the pit might be more distinctly shown. It seems not improbable that the region below the hinder half of the ridge represents the orbit. The process, *15*, behind the supposed nasal pit, may be the antorbital process.

In the dried skull of a shark at hand the interorbital region is 50 mm. wide. What may be the corresponding region of this *Edestus*, possibly a still larger animal, has been compressed until it is only 10 or 15 mm. thick. Hence, the limits of the orbit may well be difficult to distinguish. Moreover, as a result of the compression suffered, the cartilage has been more or less fractured and faulted. The upper border of the cartilaginous mass forms a smooth edge, except just over the nasal pit, where some of it has been broken off. Where the matrix has been removed from the left side of the upper shaft the latter is seen to be covered by a layer of cartilage. This is supposed to be the left side of the skull pressed against the shaft. It is possible that a part of left palato-quadrate element is included.

Behind the tooth indicated by *6*, plate 1, the upper shaft is covered with a mass of iron sulphide. This swelling probably does not represent any element of the skull. Beneath it, *7*, is the base of a tooth, the impression of whose apex is seen at *7*, plate 2, figure 1. On the broken hinder border of the block, at *16* and *17*, are seen cross sections of two other teeth, which seem to belong to the upper shaft. In case the relations of the shaft to the cranium are such as they were in life, the shaft must have extended far backward in the roof of the mouth.

It is important to note that there is no indication of a pair of shafts in either the upper or the lower jaw. This condition is in harmony with the fact that all the tooth-bearing shafts that have been discovered have been bilaterally symmetrical. Nor are there in this Iowa specimen any signs of wear on the teeth, such as one would expect to find. The specimen appears therefore to prove that the objects which alone have hitherto represented the genus *Edestus* were produced in the mouth of the shark and that there was a single one above and another below and that these played the one against the other more or less closely. It is pleasant to credit Dr. C. R. Eastman with having in various papers advocated the idea that the tooth shafts of *Edestus* and related genera belonged in the mouth. He has been disposed, however, to believe that there was a pair of them in one jaw or the other, probably the upper. The structure of these shafts shows that each must have been produced by the consolidation of a median row of symphysial teeth. As, after the manner of sharks, younger teeth were added to the hinder end of the series the older

teeth were pushed forward and out of the mouth, but instead of remaining free from the adjacent teeth and falling away, their bases cohered to form a shaft. In the species before us the outer end of the lower shaft was directed forward and downward, while the upper shaft was directed forward and upward. It is entirely improbable that the tooth found at the outer end of each of these shafts was the first tooth the animal possessed. One must therefore believe that, although the outer segments of the shaft appear to be very solidly united, those of the older teeth did, in succession, lose their hold on the younger ones and become detached.

This Iowa specimen enables us to determine which end of the shaft is the anterior and in what order the new segments were added, and here the opinion held by most writers is reversed. That end which in a former paper the writer regarded as the front end is in reality the hinder end. The bases of the crowns of the teeth are drawn out backward, not forward. The tooth which is seen at the left end of the figure of *Edestus crenulatus* [1] is not the last tooth that was formed, but the first, at least the first of those present. In his description of the type species of the genus, *E. vorax*, Doctor Leidy [2] correctly judged which was the anterior end of the fragment that he had, but he supposed that it was a part of the maxilla of some fishlike animal. Dr. J. S. Newberry,[3] in his description of *E. giganteus*, stated that the teeth, or denticles, were prolonged backward and downward into a simple point. In this opinion, as shown by the specimen at hand, he was correct. However, on the preceding page Newberry writes: "Again, *E. heinrichsi* is nearly straight, a foot long, rounded and massive at one end, thin and acute at the other; but the succession of denticles was by additions to the acute end, which must have been behind," etc., a statement that contradicts the one just referred to regarding the direction in which the enamel is prolonged. In describing the manner of growth of the mass,[4] he said: "The numerous disconnected segments of *Edestus heinrichsi*, furnished me by Mr. Butts, seem to prove conclusively that the spine was elongated by the addition of a sheath, carrying a denticle, to the extremity and underside of the preexisting series." It is to be recollected that Doctor Newberry believed that the mass was a dorsal defensive spine.

Like Newberry, the present writer held that the last-formed channeled tooth base was applied to the border of the shaft opposite the one bearing the teeth; but now it is necessary to believe that the newer tooth base was laid down in the trough of the one immediately

[1] Proc. U. S. Nat. Mus., vol. 37, 1909, pl. 12, fig. 1.
[2] Journ. Acad. Nat. Sci. Phila., ser. 2, vol. 3, p. 160.
[3] Pal. Fishes, N. A., p. 225.
[4] Idem, p. 223.

preceding it. Furthermore, since the troughlike tooth bases last produced are much shorter than the older ones, it must be that the latter continued for a long time to grow backward. This resulted in maintaining and increasing the size and the strength of the shaft.

As stated, the base of the crown of each tooth is prolonged backward. Now if we apply this rule to the tooth masses of *Helicoprion* and *Lissoprion*, we are led to the absurd conclusion that the very small teeth of the innermost coil are the ones that were last formed. The same remark will apply to *Toxoprion*. It becomes evident, therefore, that there existed some important differences, other than that of form, between *Edestus* and the genera just named.

As will be seen from the figures, many small particles are scattered over the block below the lower shaft. These appear to consist mostly of particles of decayed calcified cartilage, but there appear to be occasional scales of shagreen. Here also are seen two teeth which Doctor Eastman, on examining the specimen, recognized as belonging to the *Orodus* type. It is possible, not to say probable, that these teeth were originally attached to one of the jaws of the *Edestus*. If they were a part of the armature of *Edestus*, this fact would go far toward confirming Doctor Eastman's belief that *Edestus* had been derived from some form like *Orodus* or *Campodus*. It might be that from a shark having in the upper or the lower jaw two rows of symphysial teeth there might arise a form having but one row, enlarged and especially modified through the reduction of the other row of the pair. Something like this is seen in the usually unpaired and greatly developed canine tooth of *Monodon*. In assigning these *Orodus*-like teeth to the jaws we must consider the fact that the teeth indicated on plate 1 by the numerals *11* and *12* probably belong on the upper jaw.

The remains here described appear to represent a species hitherto unknown. It closely resembles *Edestus minor* Newberry. It differs from the latter in having the tooth shafts more strongly bent and in having the apices of the teeth more acuminate. In *E. minor*, as in the present species, the front border of each tooth is convex, but the hinder border is either nearly straight or only slightly concave for most of the length, while near the apex it becomes convex. In the new species the whole posterior border is concave and the apex of the tooth is relatively slender. It appears also that the denticulations of the teeth of *E. minor* are at right angles with the border, while in the present species they are directed distinctly toward the apex.

I propose to call the species represented by the above-described remains from Lehigh, Iowa, EDESTUS MIRUS.

As already stated, this specimen was found in the black shale overlying the Tyson seam. This seam belongs to the Des Moines stage of the "Coal Measures." For details regarding the geology of this region

the reader may consult the report on this county made by Prof. Frank A. Wilder [1] and a report on Iowa coals by Mr. Henry Hinds in volume 19 of the same survey. I am informed by Mr. David White, of the United States Geological Survey, that the Des Moines stage belongs either to the uppermost Pottsville or to the basal Allegheny. This means that the species here described lived in the earlier part of the era during which the coal beds of the eastern half of the United States were deposited. The type of *E. minor* found in Parke County, Indiana, appears to have lived at about the same time. *Edestus heinrichi* is found in coal mines that appear to have approximately the same level as those mentioned, but are possibly a little higher in the series.

It may be proper to note here that there is a specimen of *E. heinrichi* in the collection of the Iowa State Historical Society at Des Moines. It was found at Mystic, Appanoose County, Iowa.

There seems to be no certain evidence that any species of *Edestus* occurs in the upper half of the "Coal Measures."

The sharks that belonged to the genus *Edestus* must have presented a singular appearance with their straight or bent tooth shafts protruding from their mouths, especially the species *E. vorax* and *E. giganteus*, in which these organs attained a remarkable size. Nevertheless the individuals of *Helicoprion* and *Lissoprion* were still stranger objects, since each must have carried in front of the mouth a pair of weapons resembling circular saws, each 9 or 10 inches in diameter. Karpinsky's figure has seemed grotesque enough, but it probably tells only half the story. It remains now for some one to explain how the toothed whorls of *Helicoprion* were produced and attached. That of the lower jaw must have formed its segments above and in close contact with the symphysis of the lower jaw. At the same time the earlier-formed end of the last turn must have lain below the symphysis, with the apices of its teeth pointing toward this. According to Karpinsky's figure, there was the space of only 15 mm. between the apices of these teeth and the base of the shaft. The ligaments joining the right and left members of the lower jaw may be supposed to have passed in this space, besides the skin and the tissue underlying the shaft. It is, on the other hand, possible to believe that the shaft itself formed the bond of union between the two jaws and that nothing but the skin intervened between successive turns. A similar but more difficult problem confronts us in the case of the upper whorl. It will not do to push the whorl out in front of the snout, as Karpinsky has done, by making the younger part of the spiral relatively straight, for its last turn would stand out far from the preceding ones, and of this there is no evidence or probability. Besides, there would have been the same demand for a little curved portion while the first turns were being formed. The determination

[1] Geol. Surv. Iowa, vol. 12.

of the position of the upper shaft with relation to the symphysis of the upper jaws and to the snout of the animal is more difficult, but the present writer has now little doubt that nature had the problem solved in a way that permitted the presence of a spiral of teeth above and another below.

EXPLANATION OF THE PLATES.

[All the figures are three-fourths the natural size.]

PLATE 1.

1. Upper tooth shaft.
2. Lower tooth shaft.
3. Detached portion of lower shaft.
4. Seventh tooth of lower shaft.
5–7. Fifth, sixth, and seventh teeth of the upper shaft.
9. Depression occupied by left side of lower jaw.
11, 12. Smaller teeth supposed to have belonged to some of the jaws.
13. Fragment of cartilage supposed to belong to the right half of lower jaw.
14. Placed just above the nasal pit.
15. Process of cartilage, possibly the antorbital process.
16, 17. Position of two broken teeth belonging to the upper shaft.

PLATE 2.

figure 1.

2. Fragment of lower tooth shaft.
5–7. Impressions of teeth of upper shaft, indicated as on Plate 1.
8. Part of right side of lower jaw.
9. Part of the left side of the lower jaw.
10. Impression in the shale of part of the right side of the lower jaw.

figure 2.

4. The tooth indicated by the same numeral in Plate 1.
12. The tooth indicated in Plate 1 by 12.
18. The sixth tooth of the lower shaft.
19. A loose shaft tooth.
20. A tooth supposed to belong to one of the jaws.